Furman Magazine

Volume 47
Issue 2 *Summer 2004*

Article 7

6-1-2004

MOND game

John Roberts
Furman University

MOND game

'Parallel computer cluster' may help shed new light on Newton's Law.

Like Einstein's Theory of Relativity, Newton's Law of Gravity is one of the fundamental bedrocks of science.

Most schoolchildren are familiar with the result of Sir Isaac's epiphany after an apple fell from a tree and struck him on the head: Newton's Law, which states that two objects attract each other with a force proportional to the mass of each object and inversely proportional to the square of the distance between the objects.

Newton, of course, was one of history's pre-eminent minds. With his Law of Gravity and his three Laws of Motion — the most important being the Second Law, which asserts that an object's acceleration under the action of a given force is proportional to the force and inversely proportional to the object's mass — he was able to explain the motion of falling apples, cannonballs shot from a cannon, the moon orbiting the earth, and any other example known to him of one object moving in the vicinity of a much more massive object to which it is gravitationally attracted.

Johannes Kepler had earlier shown that the planets followed elliptical orbits around the sun at a speed that varied depending on their distance from the sun, but he had not been able to explain why their orbits demonstrated these characteristics. One of the triumphs of Newton's laws was their ability to predict the orbital movement of the planets. In effect, Newton built on and improved Kepler's theory.

Newton's ideas went mostly unchallenged for several centuries, in large part because they seemed to explain the movement of the planets in Earth's solar system. But when scientists developed the ability to chart the movement of objects in far-off galaxies, they began to make some interesting discoveries.

After estimating the mass of stars near the center of

BY JOHN ROBERTS

a galaxy, they would use Newton's Law of Gravity to predict how fast the outer stars should orbit the center of the galaxy. To their surprise, they found that the speed of the outer stars was often much greater than the speed predicted by Newton's Law. This led to the theory that there is additional matter in a galaxy. "Dark matter," as it is called, is defined as extra mass that isn't visible and that, therefore, has been overlooked in estimating the mass of the galaxy's central region.

Moti Milgrom, an Israeli scientist, emerged in 1983 with a different theory, suggesting that Newton's Law could be adjusted to account for the star velocity variations in galaxies. His formula, called MOND (MOdification of Newtonian Dynamics), proposed that the gravitational force law (for large separation of objects) is inversely proportional to "r," the distance between the objects, rather than to Newton's "r^2," the square of the distance. As a result, the gravitational force exerted on a star at the edge of a galaxy by the massive stars near the galaxy's center is stronger than what Newton's Law of Gravity would predict. If valid, Milgrom's formula would explain the higher-than-expected speed of the outer stars without inferring the presence of dark matter.

Milgrom's formula, though intriguing, has been difficult to test because it would require tracking the movements of thousands of stars over thousands of years.

This is where Furman's Bill Baker and Wade Shepherd enter the picture.

Baker, chair of the physics department, and Shepherd, who works in the Department of Computing and Information Services, determined that a good starting point for testing Milgrom's formula would be to network a bank of computers in a Furman physics laboratory using gridMathematica, software that links individual PCs in a parallel-processing network.

By harnessing the collective calculating power of the computers, Baker and Shepherd determined that they could apply both Newton's and Milgrom's theories to stars in a simulated "star cluster" — a grouping of thousands or even millions of stars in the same region of space. They reasoned that they could compare the speeds and other properties of the stars in the simulated clusters to those of star clusters that have actually been observed, then determine whether MOND provides a better explanation than Newton's Law for the speed of the outer stars.

Creating such a simulation, explains Baker, requires billions of calculations, enough to overwhelm many computers. He estimates that it would take one computer 30 hours to complete a simulation of a 1,000-star cluster. But networking the computers — which Baker and Shepherd did with the help of 2004 graduates Joel Olive and John Brady — allows the machines to talk to one another and thus divide the problem into manageable parts. The "parallel computer cluster" (supercomputer?) can complete a simulation in three to four minutes.

Baker points to additional benefits Furman students can derive from the project: "At very little cost and by using existing resources, we have been able to create a computer network that can be used to carry out large-scale simulations in many areas, such as classical and quantum mechanics, structural and dynamic modeling, materials science and astrophysics."

But what do the early results of the Furman simulations show? Should Newton's Law of Gravity be revised? Is this a case of MOND over matter?

While more research is needed, the findings to date indicate a significant difference between simulations that use Newton's Law of Gravity and MOND. Baker reports that, late in the evolution of a star cluster, the MOND simulations show a mean star velocity about 75 percent greater than the velocity achieved under the Newtonian model.

The "Simulation of Modified Newtonian Dynamics" project has earned considerable attention. It received the InnoVision 2003 "Innovation in Education Award," which celebrates technological excellence in the Upstate region of South Carolina, and Baker has made presentations about the project at meetings of the American Physical Society and the American Astronomical Society. He and Shepherd are continuing to fine-tune their program and hope to add more computers that will help them develop simulations on a much larger scale.

Extra mass or extra gravity? Perhaps research conducted in a Furman laboratory will eventually help clarify one of the mysteries of the universe.

Photo: An example of a star cluster — actually an unusual double star cluster known as NGC 1850. It is found in the Large Magellanic Cloud, a dwarf galaxy that orbits our own Milky Way. The photo was taken with the NASA Hubble Space Telescope in July 2001. According to the Hubble Web site, the main cluster at center is about 50 million years old; the smaller cluster at bottom right is four million years old. To view more photographs taken by the Hubble Space Telescope, visit www.hubblesite.org. **Credits:** *Space Telescope Science Institute (STScI), NASA, European Space Agency and Martino Romaniello (European Southern Observatory, Germany).*